Phase I Project Summary

Firm: Tech-X Corporation, **Contract Number:** NNX11CI14P, **Project Title:** Advanced Particle-in-Cell (PIC) Tools for Simulation of Electrodynamic Tether Plasma Interactions

Identification and Significance of Innovation:
Electrodynamic tethers are optimally suited for use in Low-Earth-Orbit (LEO) to generate thrust or drag to maneuver satellites. Advanced PIC tools can perform self-consistent 2-D and 3-D ED tether simulations to study the plasma interactions and improve the understanding of the self-induced magnetic field effects on the current collection ability of these ED tethers. These tools once validated using tether ribbon tape experiments can help NASA researchers to analyze various tether geometries in efforts to optimize tether design for space missions on a wide range of operating conditions.

Technical Objectives and Work Plan:
Objectives:
- Accurate and high-resolution PIC tether simulation, which include self-induced magnetic field effects.
- Demonstrate the tools to support optimum tether design and development for future space missions.
- Commercial tether PIC tools to support wider space research community.

Work Plan:
- Benchmark Tech-X's PIC tools on 2-D Bare ED tether problems
- Demonstrate the 2-D modeling of self-magnetic field effects on the current collection abilities of bare ED tether system
- Investigate the effects of different tether geometry configurations for space applications via simulations
- Perform electron collection experiments to positively biased tether geometries in LEO like plasma to validate simulations

Technical Accomplishments:
In Phase-I we have successfully completed our tasks and met the technical objectives proposed in the Phase-I project. We have improved the space plasma interaction simulation models exist in this field by correctly simulating the space plasma environment with current feedback and open boundary condition systems. We have successfully benchmarked 2-D VORPAL tether simulation results with OML theory and other published data. We have demonstrated that VORPAL simulations can be used for investigating the positively biased tether operation in various space environments. Our simulations analyzed and quantified how the current collection efficiency will be affected with different tether designs, geometry and bias voltages. Our predictions are in good alignment with theory and other published data. Successfully performed LEO space plasma environment experiments at CSU to study the plasma sheath structure surrounding cylindrical and tape tethers and measured the current collection results using advanced plasma diagnostic tools. Other accomplishments of this work are: Using the open boundary systems and higher-order particle weighting schemes in VORPAL, the PIC simulations of the space plasma interactions can be run a lot faster.

NASA Application(s): The off-the-shelf ion thruster discharge chamber computational tools should reduce the time spent by NASA employees developing these tools for electric propulsion systems. Tether plasma simulation tools will allow NASA researchers to determine the optimum tether design for space operations. VORPAL is already being used for electric propulsion systems like ion and Hall thrusters. Thus it makes it easier for NASA researchers to adopt it for tether type simulations.

Non-NASA Commercial Application(s): Accurate plasma modeling of ED tether can benefit other government organizations such as DoD's satellite applications as well as the commercial satellite corporations such as Boeing, Lockheed Martin and Northrop-Grumman, etc.

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